fected by phase noise contributed mainly by vibrations and air turbulence. However, the amplitude modulation associated with the cyclic phase error is not affected by vibrations and air turbulence.

Therefore, in the present approach, in order to achieve higher precision in measuring cyclic error, one measures the amplitude modulation instead of the phase modulation. The heterodyne error signal is fed to a relatively simple demodulator circuit, which removes the radio-frequency component of the heterodyne error signal, leaving only the 9-Hz amplitude modulation. The output of the demodulator is fed to a spectrum analyzer or an oscilloscope for measurement of the magnitude of the 9-Hz amplitude modulation.

This work was done by Daniel Ryan, Alexander Abramovici, Feng Zhao, Frank Dekens, Xin An, Alireza Azizi, Jacob Chapsky, and Peter Halverson of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-45157

Self-Referencing Hartmann Test for Large-Aperture Telescopes

Full aperture testing of large-aperture telescopes is performed without the need for an equally large-aperture autocollimating flat.

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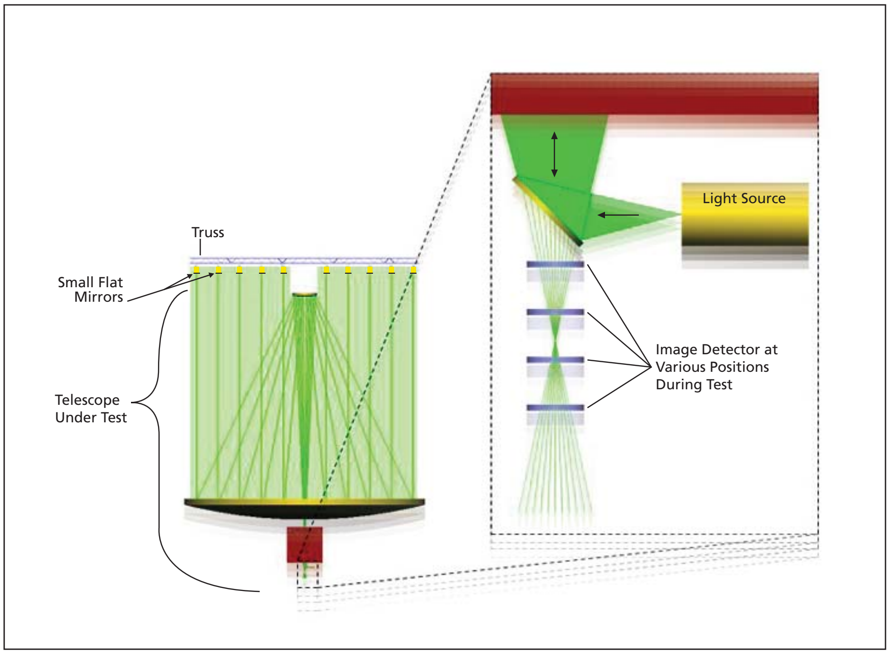
A method is proposed for end-to-end, full aperture testing of large-aperture telescopes using an innovative variation of a Hartmann mask. This technique is practical for telescopes with primary mirrors tens of meters in diameter and of any design. Furthermore, it is applicable to the entire optical band (near IR, visible, ultraviolet), relatively insensitive to environmental perturbations, and is suitable for ambient laboratory as well as thermal-vacuum environments. The only restriction is that the telescope optical axis must be parallel to the local gravity vector during testing.

The standard Hartmann test utilizes an array of pencil beams that are cut out of a well-corrected wavefront using a mask. The pencil beam array is expanded to fill the full aperture of the telescope. The detector plane of the telescope is translated back and forth along the optical axis in the vicinity of the nominal focal plane, and the centroid of each pencil beam image is recorded. Standard analytical techniques are then used to reconstruct the telescope wavefront from the centroid data. The expansion of the array of pencil beams is usually accomplished by double passing the beams through the telescope under test. However, this requires a well-corrected, autocollimation flat, the diameter or which is approximately equal to that of the telescope aperture. Thus, the standard Hartmann method does not scale well because of the difficulty and expense of building and mounting a well-corrected, large aperture flat.

The innovation in the testing method proposed here is to replace the large aperture, well-corrected, monolithic autocollimation flat with an array of small-aperture mirrors. In addition to eliminating the need for a large optic, the surface figure requirement for the small mirrors is relaxed compared to that required of the large autocollimation flat. The key point that allows this method to work is that the small mirrors need to operate as a monolithic flat only with regard to tip/tilt and not piston because in collimated space piston has no effect on the image centroids. The problem of aligning the small mirrors in tip/tilt requires a two-part solution. First, each mirror is suspended from a two-axis gimbal. The orientation of the gimbal is maintained by gravity. Second, the mirror is aligned such that the mirror normal is parallel to gravity vector. This is accomplished interferometrically in a test fixture. Of course, the test fixture itself needs to be calibrated with respect to gravity.



An **Array of Small Flat Mirrors** would be used in a self-referencing, double-pass version of the Hartmann test configuration.

Another significant advantage of the array of gimbaled small mirrors is the tolerance of the apparatus to thermal and mechanical perturbations. The individual mirrors are not affected by thermal distortions of the array structure because their orientation is self-correcting. That is, the pointing is maintained by gravity, not their supporting structure. Likewise, vibrations will cause the mirrors to sway about their equilibrium position. Thus, integrating the pencil beam image centroids over a sufficiently long period of time will make the measurements insensitive to vibration.

This work was done by Robert P. Korechoff and Jeffrey M. Oseas of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-46118